Understand the Air-Sea Coupling Processes in High Wind Conditions Using a Synthesized Data Analysis/Modeling Approach

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LONG-TERM GOAL

The long-term goal of this project is to understand the air-sea interaction processes in the coastal region in high-wind conditions and to improve the boundary layer and surface flux parameterizations for high-resolution mesoscale model (COAMPS) in high-wind conditions.

OBJECTIVES

The objectives of this year's work was to characterized the uncoupled COAMPS simulation of the gap wind outflow region in comparison with in situ aircraft observations to identified further research direction in regard to the coupled air-sea system. Funding for this project was received in August 2006. Hence, preliminary results are presented in this report.

APPROACH

In collaboration with Dr. Shouping Wang (NRL, Monterey), we have made a case analysis of the COAMPS simulation for Feb. 26 and 27 of 2004 during which measurements of the Gulf of Tehuantepec region were made by the NCAR C-130 as part of the Gulf of Tehuantepec Experiment (GOTEX). Our analyses were also aided with satellite observations, synoptic scale conditions using the Navy's NOGAPS, and surface observations and rawinsonde measurements from nearby weather stations.

WORK COMPLETED

1. COAMPS simulations were made by Dr. Shouping Wang (NRL Monterey) for the gap event on Feb 26, 2006. The NPS efforts focused on analysis of the model field, including the temporal and spatial evolution of the gap front and the boundary layer vertical structure in the gap outflow region.

2. We obtained and analyzed synoptic conditions from NOGAP forecast and surface observations and rawindsonde measurement. These analyses established the observed evolution of the gap wind and gap outflow off the Gulf of Tehuantepec (GoT).

3. Satellite observations of the GoT region were studied to quantify the movement of the gap outflow front, which was used to evaluate the COAMPS simulated gap outflow evolution.

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4. Future work includes intercomparison with aircraft measurements, ocean mixed layer modeling using COAMPS forcing, and in collaborating with NRL on 3-D ocean modeling and fully-coupled modeling.

RESULTS

Simulated Gap outflow development: COAMPS simulated development of the gap outflow is shown in Figure 1 for every 3 hours together with the leading edge position (thick yellow line) derived from the location of rope clouds in visible satellite images. Figure 1 shows that at 12Z the event was already well developed and the outflow reached hundreds of kilometers offshore. The highest winds occurred just offshore directly downstream of Chivela Pass with winds peaking at about 22 m s^{-1}. While the western progression of the leading edge and the wind speeds associated with the outflow matched that of the satellite imagery and aircraft wind measurements fairly well, the observed leading edge indicates that COAMPS did a poor job of simulating the southward and southeastward progression of the outflow.

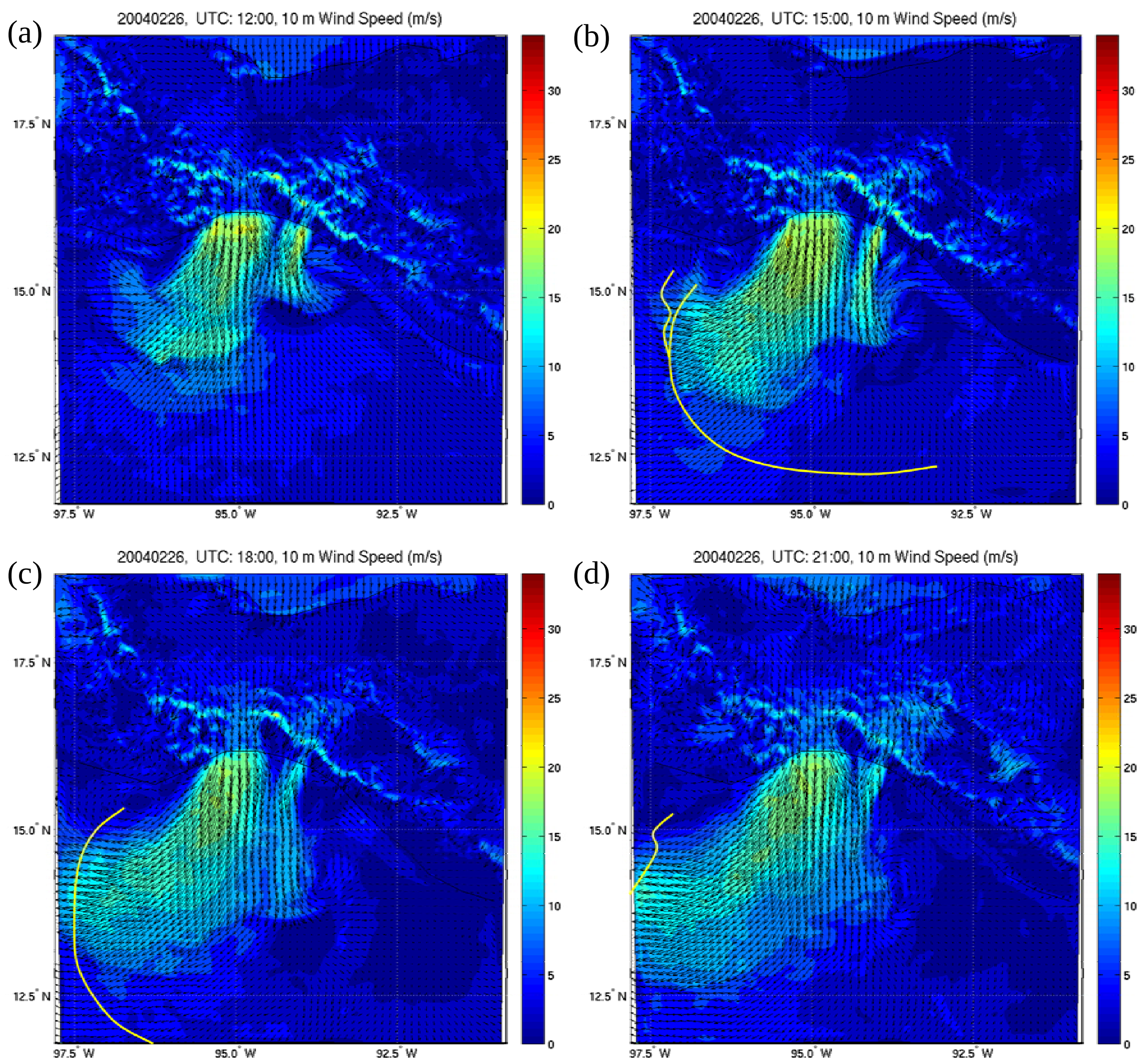

Figure 1. COAMPS simulated wind speed contours in ms^{-1} and wind vectors at 10 m analyzed on 26 February at (a) 12Z, (b)15Z, (c)18Z, and (d) 21Z. The length of the wind vector is proportional to its magnitude. The yellow lines indicate the leading edge identified from satellite imagery.

The maximum wind jet core appears to cross the 97.5W longitudinal line near 14N. This is almost two degrees north compared to that seen from the scatterometer winds at the same longitude where previous study and observations showed more southward location of the outflow jet in conditions when large scale synoptic forcing are secondary to forcing from the local topography. This model discrepancy is likely linked to some unrealistic divergence feature at the leading edge to the south. Such divergence features disrupt the flow to the south and favor the formation of the cyclonic eddy to the east. However, in examining multiple gap events in the region using scatterometer wind, we have not confirmed the presence of similar divergence pattern. Further study is needed to identify the source of this divergence pattern and how it is related to the misrepresentation of the leading edge to the south.

Spatial and time variation of surface fluxes in the simulated gap outflow region: The gap outflow region is an area with strong air-sea coupling. Figure 2 shows the temporal and spatial variation of the sensible heat flux as an example of the air-sea exchange occurring in the outflow region. Here, we find the largest sensible heat flux at the mouth of the gulf as a result of strong wind and cool air out of the

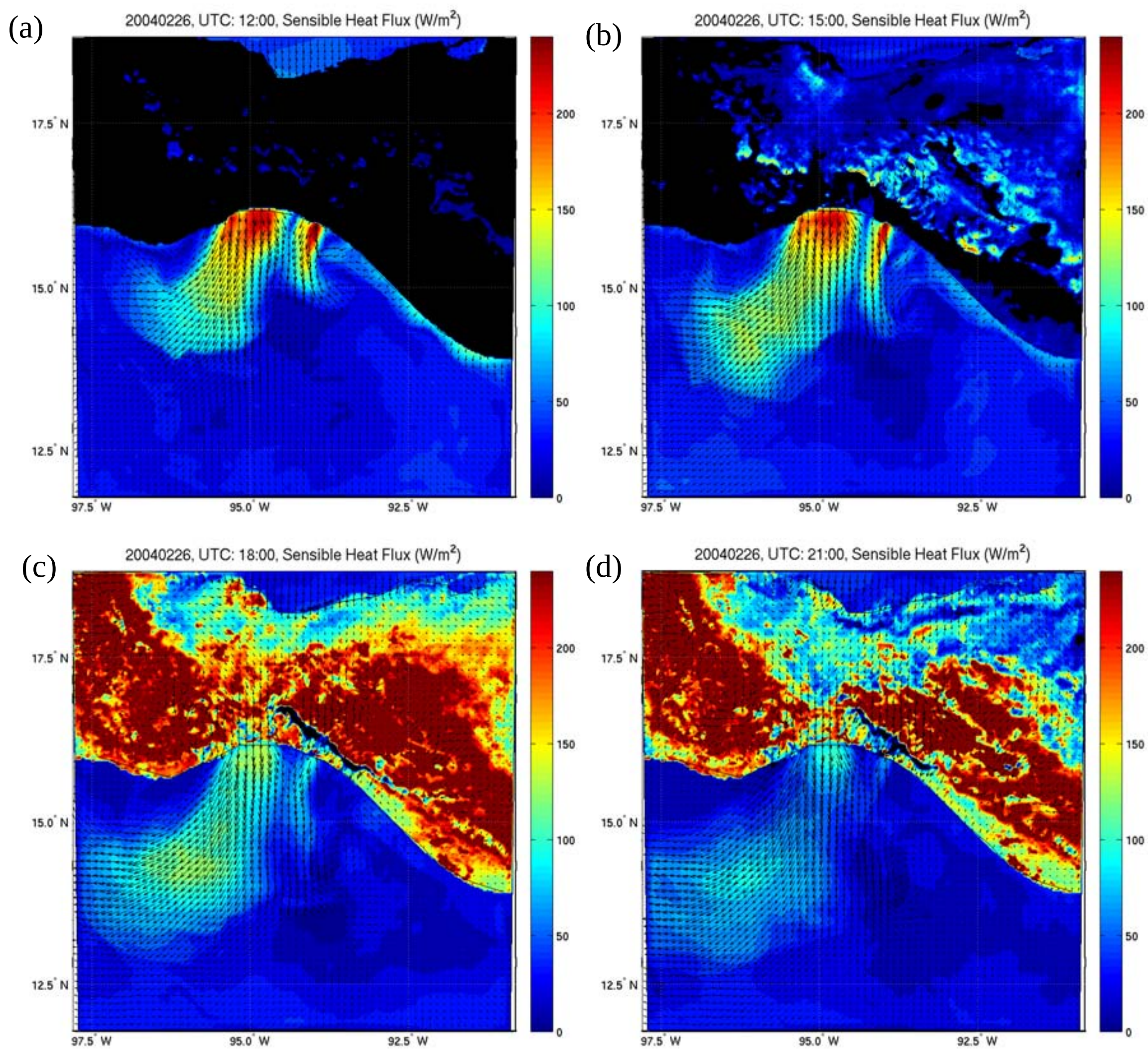

Figure 2. Same as Figure 1, except for sensible heat flux in W m^{-2}.

gap, particularly at nighttime. As the air overland warms up after sunrise, there is significant decrease of the heat flux at the mouth of the gulf and a second heat flux center further down the jet axis became apparent. Similar variations are also seen in latent heat flux although the diurnal variation is not as significant. Their implication to the upper ocean response to the overpass of the gap outflow will be examined in the future research.

Boundary layer evolution along the jet core. A close look at the vertical cross-section along the jet core (Figure 3) reveals several important features of the boundary layer development along the jet core where COAMPS does a reasonably good job. Here we can identify three major characteristics of the jet and the boundary layer. 1) The jet core extend about 200 km offshore with the maximum wind at the boundary layer top; 2) The flow before Point C, about 200 km from the mouth of the gulf, is supercritical, while the flow after Point C is subcritical as seen from the estimated Froude number. As a result, there is a hydraulic jump of the boundary layer at point C where the boundary layer height jumped from 500 m to 1100 m; 3) Strong convergence occurs at the gap outflow front resulting in significant upward motion, increase of boundary layer height, and accumulation of water vapor behind the front. This convergence zone also triggered broader downdraft behind the front between the hydraulic jump and the leading front that causes the decrease of boundary layer height.

IMPACT/APPLICATIONS

The Gulf of Tehuantepec is a natural laboratory for studying air-sea interaction in moderate to high-wind conditions given the frequent occurrence of the gap wind event. Our study in FY06 is the beginning of a series effort in understanding the coupling between the atmosphere and the ocean and particularly on issues one should deal with in a fully coupled mesoscale model such as COAMPS.

TRANSITIONS

The results of this project will contribute to establish fully coupled atmosphere/ocean models.

RELATED PROJECTS

Related project is the CBLAST project for surface flux parameterization (Award N0001406WR20253 and N0001406WX20664 to NRL Monterey) and the Award N0001406WR20081 for surface flux parameterization in Monterey Bay.

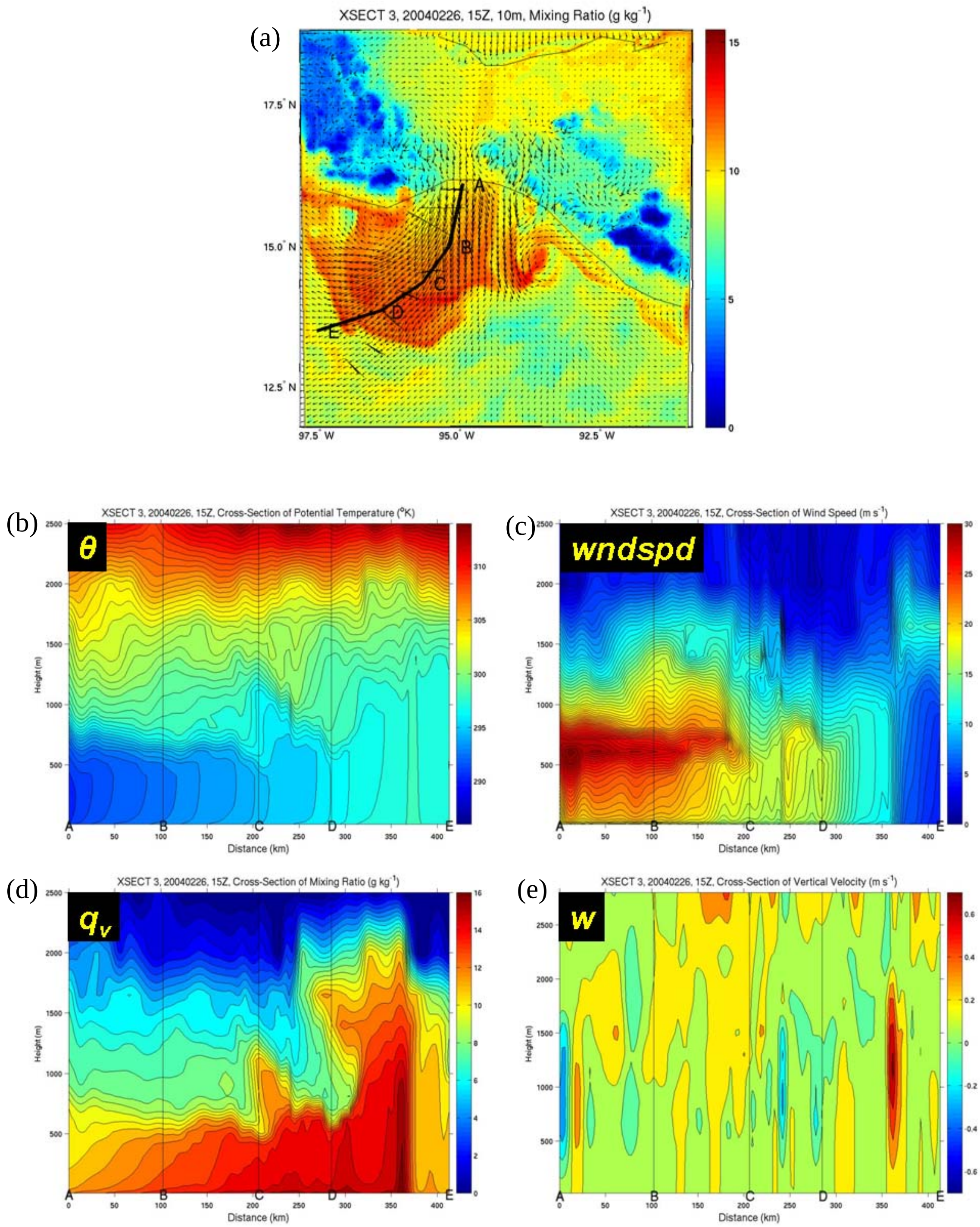

Figure 3. (a) Horizontal variation of water vapor at the time the vertical cross-section is discussed. Reference points on the cross-section plot are denoted here. The thin black lines shows the aircraft flight track available on this day. (b) to (e): Vertical thermodynamic structure along the outflow jet core. (b) potential temperature, (c) wind speed, (d) mixing ration, and (e) vertical velocity.